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Östrup et al.

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(54) METHOD AND SYSTEM FOR IMPROVING NETWORK RESOURCE UTILIZATION IN A CELLULAR COMMUNICATION SYSTEM

(75) Inventors: **Nils Peter Östrup**; **Per Johan Schultz**; **Lars Folke Johansson**, all of Linköping; **Lars Håkan Palm**, Lund, all of (SE)

(73) Assignee: **Telefonaktiebolaget LM Ericsson (publ)** (SE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/134,202**

(22) Filed: **Aug. 14, 1998**

(51) **Int. Cl.**[7] **H04Q 7/20**

(52) **U.S. Cl.** **455/444**; 455/436; 455/449; 455/450; 455/453; 370/328; 370/331

(58) **Field of Search** 455/436, 444, 455/449, 450, 453, 433, 445; 370/328, 329, 331, 352

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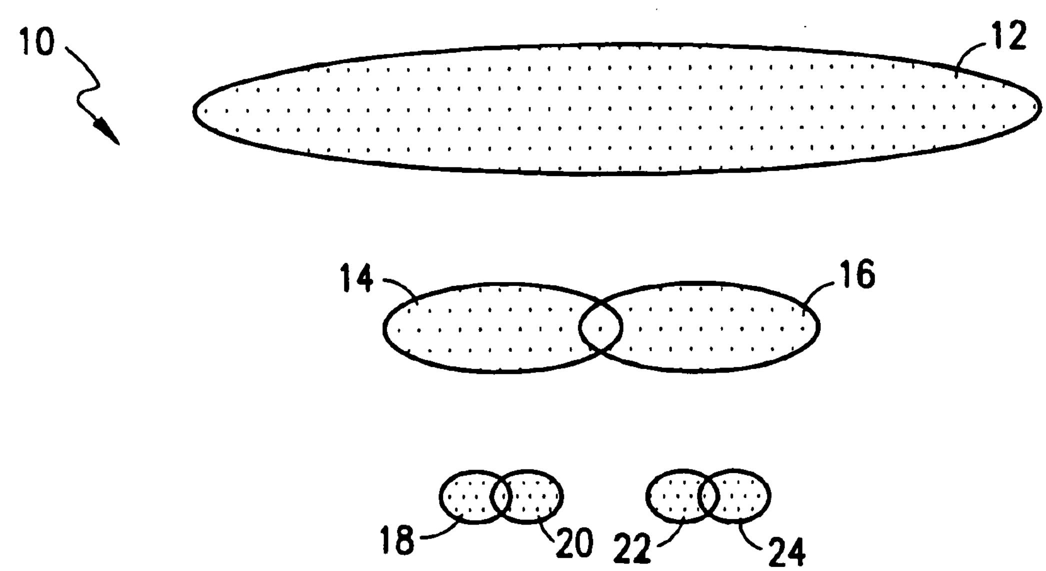
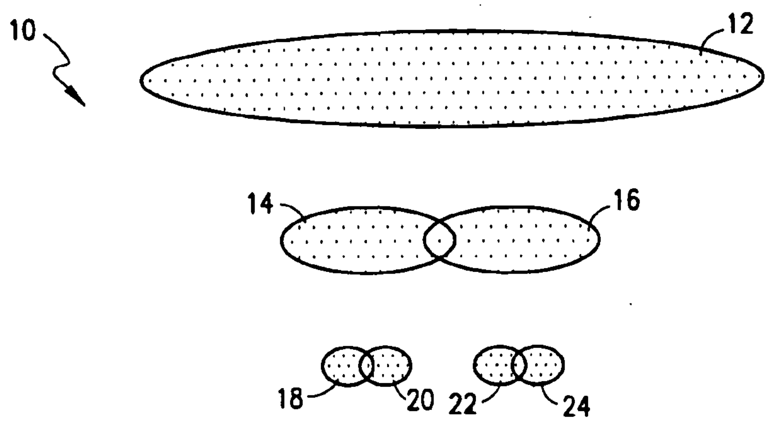
Primary Examiner—Dwayne Bost
Assistant Examiner—Temica M. Davis
(74) *Attorney, Agent, or Firm*—Jenkens & Gilchrist, A Professional Corporation

(57) **ABSTRACT**

A hierarchically structured cellular network is disclosed. When an active mobile station requests a service that requires the use of a network resource not available in the cell handling the ongoing call (or, alternatively, during call set up), the network checks for cells on the higher levels to determine if the required resource is available. If the resource is available in a higher level cell, the call is handed over to that cell and the resource is allocated to the call. The call can be maintained in the higher level cell until the resource is no longer needed, or a "better" cell capable of providing the required resource is found.

19 Claims, 2 Drawing Sheets




10
12
14
16
18
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22
24

FIG. 1

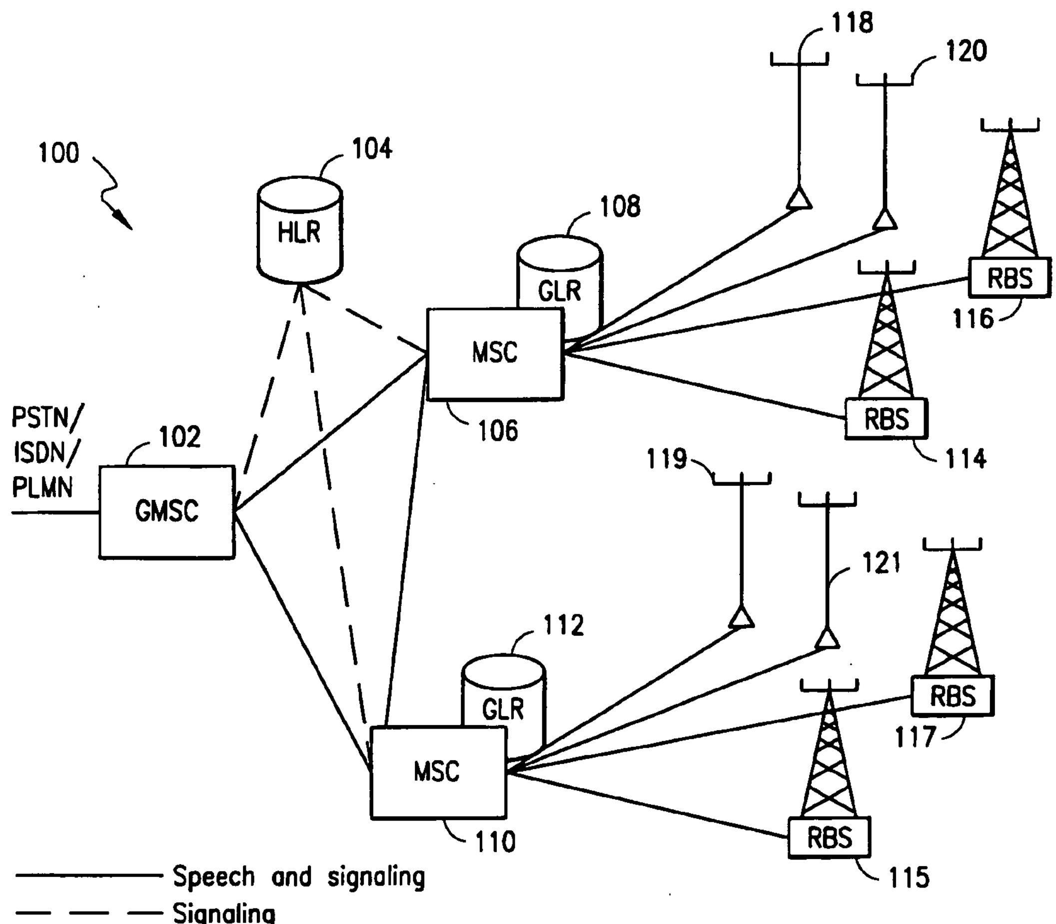
100
104
HLR
108
GLR
MSC
106
118
120
RBS
116
RBS
114
PSTN/
ISDN/
PLMN
102
GMSC
119
121
112
GLR
RBS
117
MSC
110
RBS
115
Speech and signaling
Signaling

FIG. 2

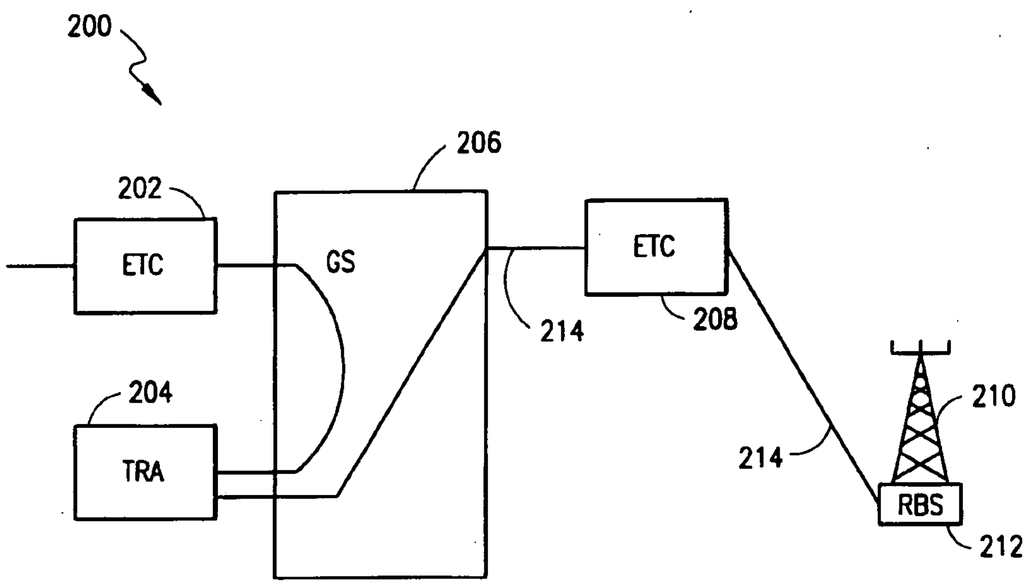

FIG. 3

METHOD AND SYSTEM FOR IMPROVING NETWORK RESOURCE UTILIZATION IN A CELLULAR COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The present invention relates in general to the mobile communications field and, in particular, to a method and system for improving utilization of network resources with handovers in a cellular communication system.

2. Description of Related Art

A hierarchical (layered) cell structure can be used as one approach to obtain higher network capacities in mobile radiotelephone systems. For example, Hierarchical Cell Structures (HCSs) are being used in Personal Digital Cellular (PDC) System radio networks in Japan, so that cells of different sizes can be used to cover the same geographical areas. Using such a hierarchical cell structuring approach, the PDC networks' radio channel frequencies can be re-used to a much greater extent than with conventional cell structures, which results in higher capacity (traffic load). In that regard, a hierarchically structured network can employ a handover procedure to order a mobile station (MS) to move from one radio channel frequency to another in the same cell or a different cell.

A problem that arises with such cell structuring approaches is that certain, special communication resources provided by the radio networks are not necessarily maintained and made available in cells at all levels, especially in those networks where higher capacities are desired. An example of such a resource typically not made available in lower level cells is a full-rate traffic channel, or a circuit-switched data transmission service. In radio networks utilizing a HCS, the operators typically configure the networks to provide these resources in the higher level, broader coverage cells (e.g., layer 3 or "umbrella" cells in a three-layered HCS network). As such, in existing mobile systems, an MS accesses the "best" (e.g., higher carrier-to-interference or carrier-to-adjacent ratio) available cell in the radio network. The network then assigns a traffic channel (TCH) to the MS in a cell on the lowest possible level. Consequently, when an active MS requests a service that requires the use of a specific resource (e.g., full-rate traffic channel, or circuit-switched data transmission service), and if that resource is not available in the cell handling the ongoing call, the requested service will not be provided for that call. Therefore, the network will most likely disconnect that call. However, as described in detail below, the present invention successfully resolves this problem and other related problems.

SUMMARY OF THE INVENTION

In accordance with a preferred embodiment of the present invention, in a HCS network, when an active MS requests a service that requires the use of a network resource not available in the cell handling the ongoing call (or, alternatively, during call set up), the network checks for cells on the higher levels to determine if the required resource is available. If the resource is available in a higher level cell, the "call" is handed over to that cell and the resource is allocated to the call. The call can be maintained in the higher level cell until the resource is no longer needed, or a "better" cell capable of providing the required resource is found.

An important technical advantage of the present invention is that a network operator can create a radio network plan based on the capacities of different communication resources.

Another important technical advantage of the present invention is that network resource utilization is increased significantly over conventional approaches.

Yet another important technical advantage of the present invention is that the flexible resource utilization allows more calls to be set up in the lower layer cells, which allows mobile stations to transmit at lower power levels and thus save battery power.

Still another important technical advantage of the present invention is that the flexible resource utilization that allows more calls to be set up in the lower layer cells, also reduces the total interference level in the network.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

FIG. **1** is a diagram that illustrates an exemplary hierarchical cell structure for a mobile radiotelephone network, which can be used to implement a preferred embodiment of the present invention;

FIG. **2** is a simplified block diagram of an exemplary cellular network that can be used to implement the preferred embodiment of the present invention; and

FIG. **3** is a simplified block diagram that illustrates an exemplary mobile base station subsystem that can be associated with one or more mobile services switching centers and radio base stations in the cellular network shown in FIG. **2** to implement the preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the present invention and its advantages are best understood by referring to FIGS. **1–3** of the drawings, like numerals being used for like and corresponding parts of the various drawings.

Essentially, in accordance with a preferred embodiment of the present invention, in a hierarchically structured or layered cellular network, when an active MS requests a service that requires the use of a network resource not available in the cell handling the ongoing call, the network checks for cells on the higher levels to determine if the required resource is available. If the resource is available in a higher level cell, the "call" is handed over to that cell and the resource is allocated to the call. The call can be maintained in the higher level cell until the resource is no longer needed, or a "better" cell capable of providing the required resource is found.

Specifically, FIG. **1** is a diagram that illustrates an exemplary hierarchical cell structure (**10**) for a mobile radiotelephone network, which can be used to implement a preferred embodiment of the present invention. The exemplary HCS **10** shown represents a three-layer cell structure, with at least one "umbrella" cell **12** at the highest level (e.g., layer **3**), a plurality of "normal" cells **14**, **16** at the next lower level (e.g., layer **2**), and a plurality of "micro" cells **18**, **20**, **22**, **24** at the lowest level (e.g., layer **1**) in the hierarchy. Notably, although not explicitly shown, the radio network can include more than one of such "umbrella" cells, along with corresponding sets of "normal" and "micro" cells. Also, the HCS concept described herein can be extended to include one or more additional levels of cells (e.g., so-called "pico" cells and/or "macro" cells)

FIG. **2** is a simplified block diagram of an exemplary cellular network (**100**) that can be used to implement the

preferred embodiment of the present invention. The exemplary network **100** includes a gateway mobile services switching center (GMSC) **102** connected to a home location register **104** and a plurality of MSCs **106**, **110**. Essentially, the GMSC **102** functions to connect the network **100** to other networks, and is the entry/exit point for calls from/to other networks to/from mobile subscribers. The HLR **104** is a database that contains subscriber information including the current location of the subscribers' MSs in the network. The MSCs **106**, **110** in combination with their respective gateway location registers (GLRs) **108**, **112** control the routing of calls, location registrations, and handovers. The GLRs **108**, **112** are databases that are responsible for storing and updating subscriber information for the MSs located in their respective MSC/GLR coverage areas. The MSCs **106**, **110** are connected to a respective plurality of radio base stations (RBSs) **114**–**121**, each of which defines a cell. As described in detail below, certain of the cells defined by the RBSs **114**–**121** can represent certain of the cells **12**–**24** shown in FIG. **1**. The subscribers' MSs (not shown) are connected to an MSC **106** or **110** via a radio air interface and an RBS **114**–**121**.

FIG. **3** is a simplified block diagram that illustrates an exemplary mobile base station subsystem (MBS) **200** that can be associated with one or more of the MSC/GLRs and RBSs in the cellular network **100** (FIG. **2**) to implement the preferred embodiment of the present invention. For example, an MBS (**200**) associated with the MSC/GLR **106**/**108** can provide communications resources for certain of the RBSs (e.g., **114**, **116**) and the cell or cells defined thereby (e.g., "umbrella" cell **12** or "normal" cells **14**, **16** in FIG. **1**). At this point, it is useful to describe some exemplary communications resources (and associated concepts) that can be provided by the MBS shown.

In the context of a PDC system (but not limited to just this system), the RBSs **114**, **116** can include dual rate equipment that provides resources capable of carrying full rate and half rate connections. Such dual rate equipment provides three dual rate channel pairs. As such, the "channel rate" (e.g., full rate or half rate) indicates the channel rate currently in use for a traffic channel. A "dual rate channel pair" denotes the channels on dual rate equipment that together provide a resource capable of carrying one full rate connection or two half rate connections. Such a dual rate channel pair comprises the channels corresponding to the radio air interface time slots TS0/TS3, TS1/TS4, or TS2/TS5.

A "dual rate traffic channel" denotes a traffic channel included in a dual rate channel pair, which is capable of carrying a half rate connection. Together with the other channel in the dual rate channel pair, the dual rate traffic channel is capable of carrying a full rate connection. A full rate traffic channel represents a traffic channel carrying a full rate connection. In the PDC radio air interface, for example, a full rate traffic channel corresponds to one full rate time slot, TS0–TS2. One full rate time slot corresponds to two half rate time slots. A half rate traffic channel represents a traffic channel carrying a half rate connection. In the PDC radio air interface, for example, a half rate traffic channel corresponds to one half rate time slot, TS0–TS5.

Returning to FIG. **3**, the exemplary MBS **200** includes a plurality of exchange terminal circuits (ETCs) **202**, **208**, which function as trunk interfaces (e.g., bit rate adapters) between the group switch **206** and other networks and transceiver (TRX) **212** in the RBS **210**. The group switch **206** can switch the calls in order to include or exclude the transcoder rate adaptor (TRA) **204** in or out of the connection. The TRA-TRX link **214** is a connection between the TRA **204** and TRX **212**, which can carry a plurality of full, half, or dual rate speech channels.

In this embodiment, the traffic functions in the MBS **200** handle the radio channel connections in this part of the network **100**, which includes, for example, controlling certain physical channels, handling all logical channels, and controlling the RBS **210** and TRA **204** in the MSC (**106**). The TRA **204** performs a rate conversion from the 64 kbps Pulse Code Modulation (PCM) links used in the group switch **206** and trunk lines to the rates used in the speech connections. As such, the group switch **206** can switch the TRA **204** into the connection if a rate conversion is needed.

Depending on the traffic, the TRA **204** can operate in a number of different modes. In one mode, the TRA **204** converts 11.2 kbps Vector-Sum Excited Linear Prediction (VSELP) encoded speech data (speech connection for the network MSs involved) into a 64 kbps μ-law PCM coded speech signal. This mode is used when the network MS is connected to any terminal other than another network MS. In a second mode of operation, if there is a call from one network MS to another network MS, the TRA **204** does not convert the signal from the MS, but transports the 11.2 kbps VSELP encoded speech signal to the network using a 64 kbps unrestricted digital channel. This mode is valid only for full rate channels in the PDC, and is used to eliminate the potential for encoding/decoding the speech data twice, which could have occurred because of the MS-to-MS call. In a third mode of operation, the TRA **204** can operate in a non-speech data mode (e.g., circuit-switched data transmission service mode). In the PDC, this mode is valid only for full rate channels.

For this example, it can be assumed that the lower layer cells (e.g., **14**, **16**) in the network **10** can provide multiplexing for each TRX used. As such, in the PDC, two TRA-TRX links **214** in each of these cells can be multiplexed into one 64 kbps time slot. Consequently, given this resource limitation, only one circuit-switched data transmission service call per TRX (e.g., **212**) can be set up in each of these cells. In other words, the capacity for carrying circuit-switched data transmission service calls is relatively low in the lower layer cells.

On the other hand, for this PDC example, it can be assumed that no multiplexing is provided for the TRXs (**212'**) in the higher layer cells (e.g., **12**) in the network.

Consequently, given the absence of this resource limitation, all three of the time slots used by each TRX (**212'**) can carry circuit-switched data transmission service calls. In other words, the capacity for carrying circuit-switched data transmission service calls is relatively high in the higher layer cells (e.g., **12**).

More specifically with respect to the network exemplified by FIGS. **1**–**3**, assume that each RBS **210'** (or, for example, **114**, **116**) that defines the higher layer cells (e.g., **12**) includes **10** TRXs, with each TRX capable of handling **3**–**6** speech channels or **1**–**3** non-speech (data) channels. Also, each RBS **210** (or, for example, **118**, **120**) that defines the lower layer cells (e.g., **14**, **16**) includes **2** TRXs, with each such TRX capable of handling **3**–**6** speech channels or **1**–**3** non-speech channels. Under this scenario, if the lower layer cells (e.g., **14**, **16**) are using multiplexing on the respective TRA-TRX links (e.g., **214**), then each of these lower layer cells can set up only two non-speech calls.

In a conventional network, if there were two such ongoing calls in one of these lower layer cells, and a third call were to request a circuit-switched data transmission service in that cell, then the network would refuse to provide the circuit-

switched data transmission service resource for that call. Ultimately, the network likely would disconnect that call. However, in accordance with the preferred embodiment of the present invention, the network **10/100** determines whether the higher layer cell (**12**) has channels available (e.g., not in use) that can carry the requested circuit-switched data transmission service, and performs a conventional inter-cell handover for that MS and call, from the lower layer cell to an appropriate channel in the higher layer cell. The MSC/GLR (**106/108**) stores pertinent information about which resources are available in which cells, and controls the inter-cell handover procedure. The requested circuit-switched data transmission service is then provided for that call by the resource in the higher layer cell. Notably, although the exemplary embodiment described above deals with a hierarchical relationship between cells **12** and **14, 16**, the invention is not intended to be so limited. For example, the hierarchical relationship and inter-cell handover can be between one of the lower layer cells **18, 20, 22, 24** and one of the higher layer cells **14, 16**. In summary, if a service/resource is not provided by one (layer) cell, but can be provided by another (layer) cell, then (in accordance with the present invention) the network can hand over the MS making the call (and requesting the service) to a cell in the layer capable of handling that service and call. The network can maintain the call in the cell capable of handling that service, until the call is disconnected, the "special" resource is no longer required for that call, or a "better" cell with appropriate resources that can provide the service is found. In the last case, the network MSC can then institute a hand over to transfer the call to the "better" cell.

Although a preferred embodiment of the method and apparatus of the present invention has been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

What is claimed is:

1. A method for utilizing communication resources in a layered cellular network, wherein a mobile station is not at the edge of a cell comprising the steps of:

invoking a circuit-switched data transmission service associated with a communication resource during a call in a first layer cell;

determining whether said communication resource is available during said call in said first layer cell;

if said communication resource is not available during said call in said first layer cell, determining whether said communication resource is available during said call in a second layer cell;

if said communication resource is available during said call in said second layer cell, handing off said call from said first layer cell to said second layer cell.

2. The method of claim 1, wherein said call comprises a call set up procedure.

3. The method of claim 1, wherein said first layer cell is a lower level cell than said second layer cell.

4. The method of claim **1**, wherein said layered cellular network comprises a hierarchical cell structure.

5. The method of claim **1**, wherein said layered cellular network comprises a layered PDC network.

6. The method of claim **1**, wherein said communication resource comprises a full rate traffic channel.

7. The method of claim **1**, wherein said first layer cell comprises a normal cell.

8. The method of claim 1, wherein said first layer cell comprises a micro-cell.

9. The method of claim **1**, further comprising the steps of:

determining whether said communication resource is available during said call in another cell; and

if said communication resource is available during said call in said another cell, handing off said call from said second layer cell to said another cell.

10. A multi-layered cellular network, wherein a mobile station is not at the edge of a cell, comprising:

a first base station defining a first layer cell in said cellular network; and

a second base station defining a second layer cell in said cellular network, said cellular network further comprising:

means for invoking a non-speech related service associated with a communication resource during a call in said first layer cell;

determining whether said communication resource is available during said call in said first layer cell;

if said communication resource is not available during said call in said first layer cell, determining whether said communication resource is available during said call in a second layer cell;

if said communication resource is available during said call in said second layer cell, handing off said call from said first layer cell to said second layer cell.

11. The multi-layered cellular network of claim **10**, wherein said call comprises a call set up procedure.

12. The multi-layered cellular network of claim **10**, wherein said first layer cell is a lower level cell than said second layer cell.

13. The multi-layered cellular network of claim **10**, wherein said layered cellular network comprises a hierarchical cell structure.

14. The multi-layered cellular network of claim **10**, wherein said layered cellular network comprises a layered PDC network.

15. The multi-layered cellular network of claim **10**, wherein said communication resource comprises a full rate traffic channel.

16. The multi-layered cellular network of claim **15**, wherein said service comprises a data service.

17. The multi-layered cellular network of claim **15**, wherein said service comprises a circuit-switched data transmission service.

18. The multi-layered cellular network of claim **10**, wherein said first layer cell comprises a normal cell.

19. The multi-layered cellular network of claim **10**, wherein said first layer cell comprises a micro-cell.

* * * * *

US006215782B1

(12) **United States Patent**
Buskens et al.

(10) **Patent No.: US 6,215,782 B1**
(45) **Date of Patent: *Apr. 10, 2001**

(54) **METHOD FOR RECONNECTING CALLS IN A WIRELESS TELECOMMUNICATIONS SYSTEM**

(75) Inventors: **Richard Wayne Buskens**, Middletown, NJ (US); **Thomas F. La Porta**, Thornwood, NY (US); **Arun Narayan Netravali**; **Krishan Kumar Sabnani**, both of Westfield, NJ (US)

(73) Assignee: **Lucent Technologies Inc.**, Murray Hill, NJ (US)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/771,740**

(22) Filed: **Dec. 20, 1996**

(51) **Int. Cl.**[7] **H04J 3/06**

(52) **U.S. Cl.** **370/350**; 345/450

(58) **Field of Search** 370/438, 439, 370/362, 363, 364, 522, 350, 503, 237, 351, 352, 454; 455/423, 445, 502, 509, 510, 516, 524, 442, 450, 452, 455, 464, 503, 504, 505, 517, 523, 526

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5,826,186	*	10/1998	Mitchell et al.	455/410
5,884,174	*	3/1999	Nagarajan et al.	455/436
5,943,334	*	8/1999	Buskeno et al.	370/350

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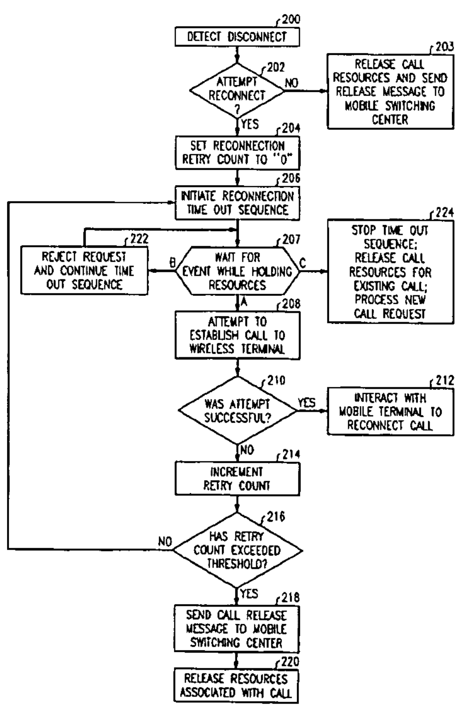
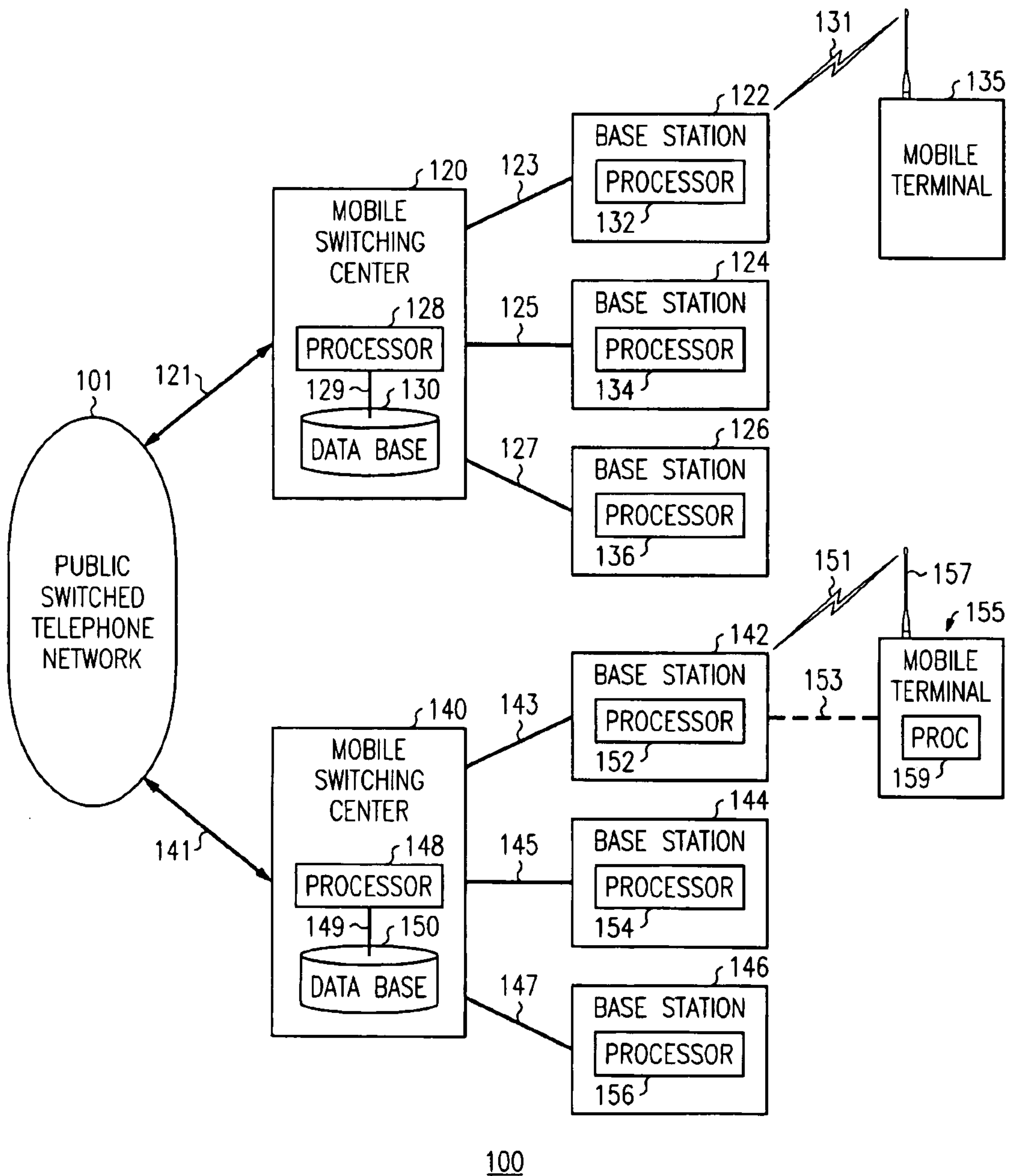
Primary Examiner—Dang Ton
(74) *Attorney, Agent, or Firm*—Werner Ulrich

(57) **ABSTRACT**

A method for reconnecting calls affected by a loss of synchronization comprises detecting disconnect of a call and initiating a time-out sequence during which reconnection attempts are performed. The reconnection time-out sequence may be incremented a predetermined number of times before reconnection attempts are terminated and the call is released. Further, a mobile switching center and a serving base station may selectively determine whether reconnection attempts are to be made. Advantageously, resources associated with a call affected by a loss of synchronization are held for a predetermined time. If reconnection is successful, the held resources are bridged to new air traffic channels resulting in enhanced network efficiency.

19 Claims, 5 Drawing Sheets




131
135
122
MOBILE TERMINAL
BASE STATION
PROCESSOR
132
120
123
MOBILE SWITCHING CENTER
124
BASE STATION
128
125
PROCESSOR
PROCESSOR
134
101
121
129
130
DATA BASE
126
127
BASE STATION
PROCESSOR
136
PUBLIC SWITCHED TELEPHONE NETWORK
151
157
155
142
MOBILE TERMINAL
BASE STATION
153
PROCESSOR
PROC
140
143
152
159
MOBILE SWITCHING CENTER
144
BASE STATION
141
148
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PROCESSOR
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BASE STATION
PROCESSOR
156
100

FIG. 1

FIG. 2

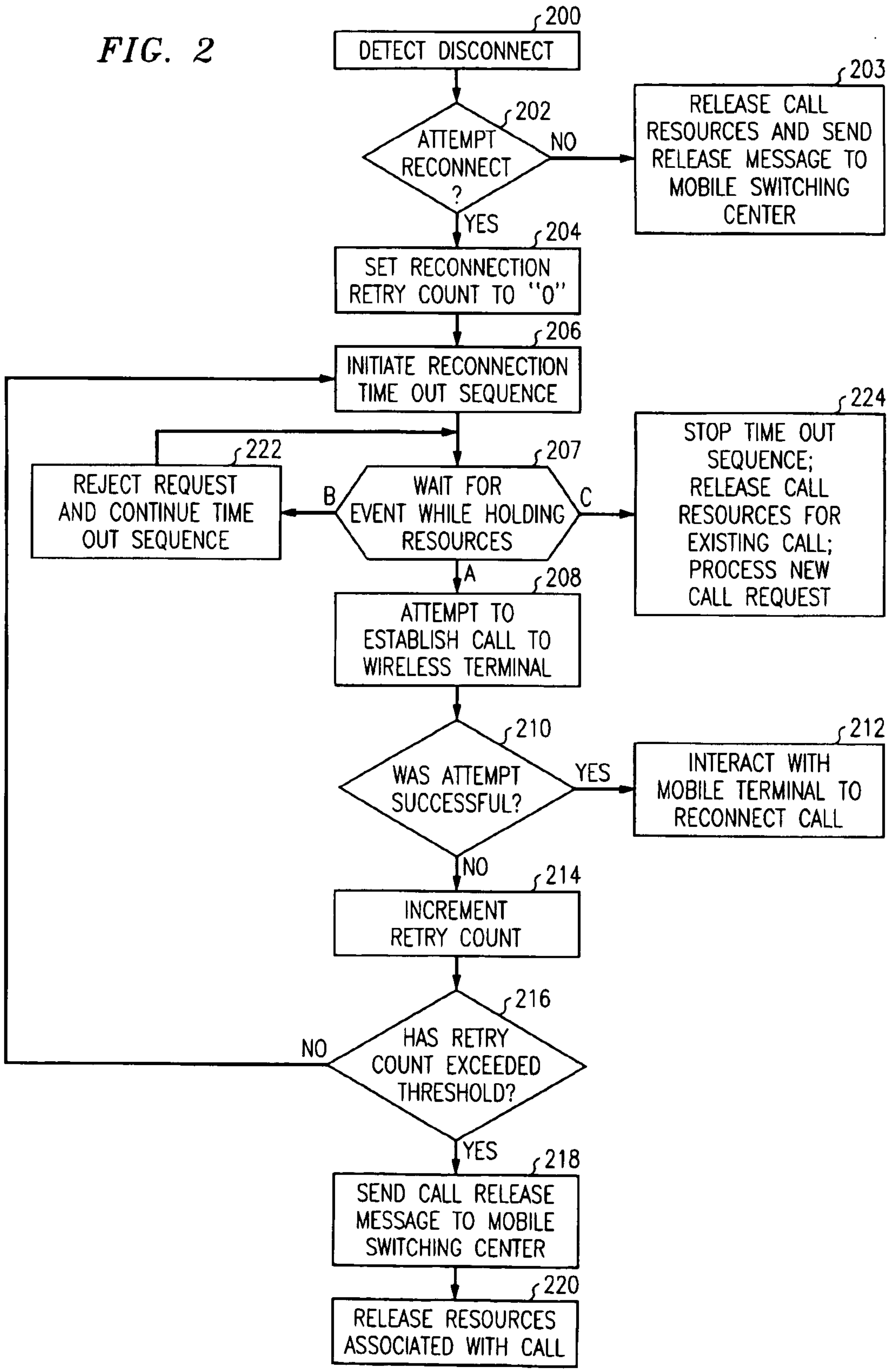

200
DETECT DISCONNECT
202
ATTEMPT RECONNECT ?
NO
203
RELEASE CALL RESOURCES AND SEND RELEASE MESSAGE TO MOBILE SWITCHING CENTER
YES
204
SET RECONNECTION RETRY COUNT TO "0"
206
INITIATE RECONNECTION TIME OUT SEQUENCE
222
REJECT REQUEST AND CONTINUE TIME OUT SEQUENCE
B
207
WAIT FOR EVENT WHILE HOLDING RESOURCES
C
224
STOP TIME OUT SEQUENCE; RELEASE CALL RESOURCES FOR EXISTING CALL; PROCESS NEW CALL REQUEST
A
208
ATTEMPT TO ESTABLISH CALL TO WIRELESS TERMINAL
210
WAS ATTEMPT SUCCESSFUL?
YES
212
INTERACT WITH MOBILE TERMINAL TO RECONNECT CALL
NO
214
INCREMENT RETRY COUNT
216
HAS RETRY COUNT EXCEEDED THRESHOLD?
NO
YES
218
SEND CALL RELEASE MESSAGE TO MOBILE SWITCHING CENTER
220
RELEASE RESOURCES ASSOCIATED WITH CALL

FIG. 3

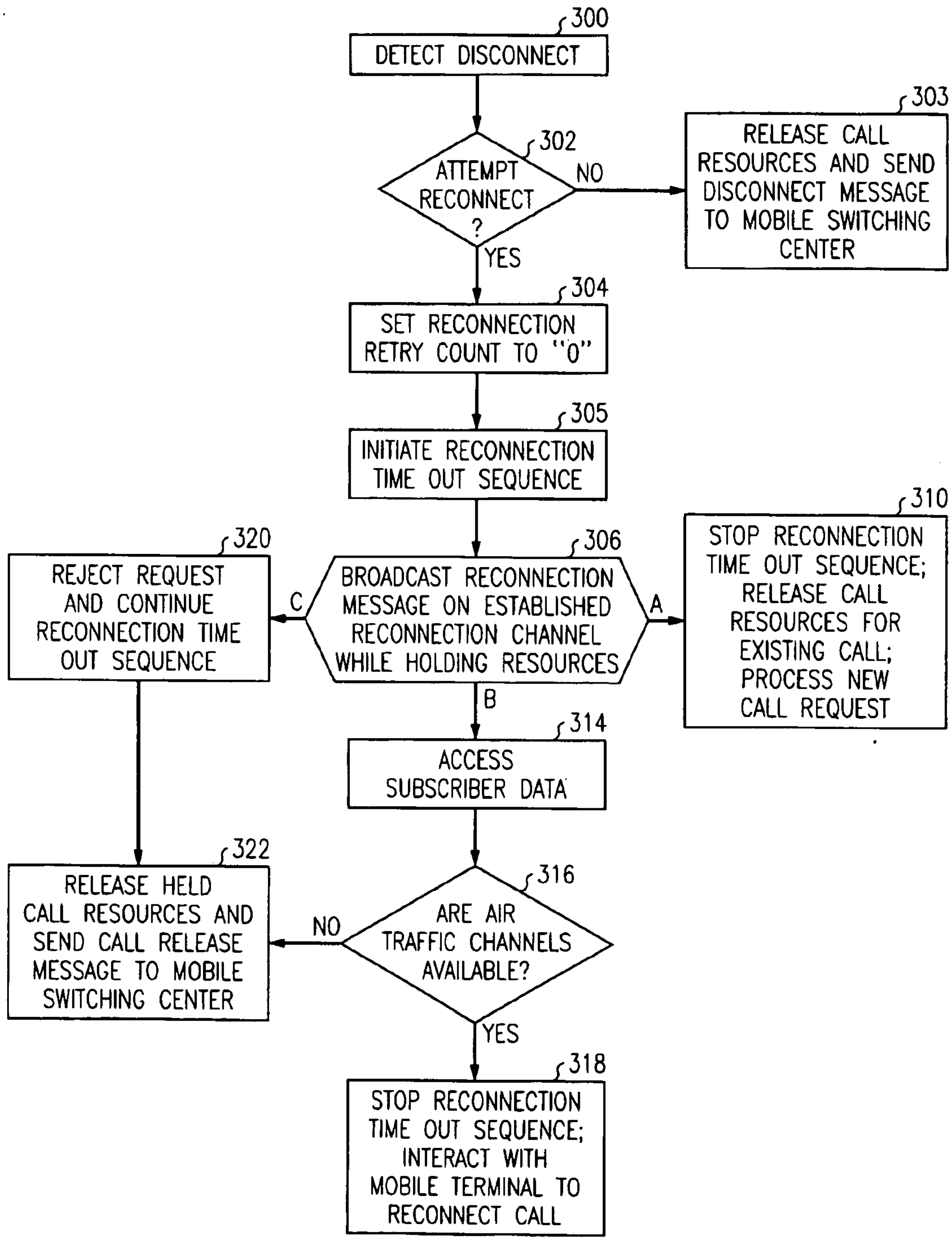

300
DETECT DISCONNECT
302
ATTEMPT RECONNECT ?
NO
303
RELEASE CALL RESOURCES AND SEND DISCONNECT MESSAGE TO MOBILE SWITCHING CENTER
YES
304
SET RECONNECTION RETRY COUNT TO "0"
305
INITIATE RECONNECTION TIME OUT SEQUENCE
306
BROADCAST RECONNECTION MESSAGE ON ESTABLISHED RECONNECTION CHANNEL WHILE HOLDING RESOURCES
A
310
STOP RECONNECTION TIME OUT SEQUENCE; RELEASE CALL RESOURCES FOR EXISTING CALL; PROCESS NEW CALL REQUEST
C
320
REJECT REQUEST AND CONTINUE RECONNECTION TIME OUT SEQUENCE
B
314
ACCESS SUBSCRIBER DATA
316
ARE AIR TRAFFIC CHANNELS AVAILABLE?
NO
322
RELEASE HELD CALL RESOURCES AND SEND CALL RELEASE MESSAGE TO MOBILE SWITCHING CENTER
YES
318
STOP RECONNECTION TIME OUT SEQUENCE; INTERACT WITH MOBILE TERMINAL TO RECONNECT CALL

FIG. 4

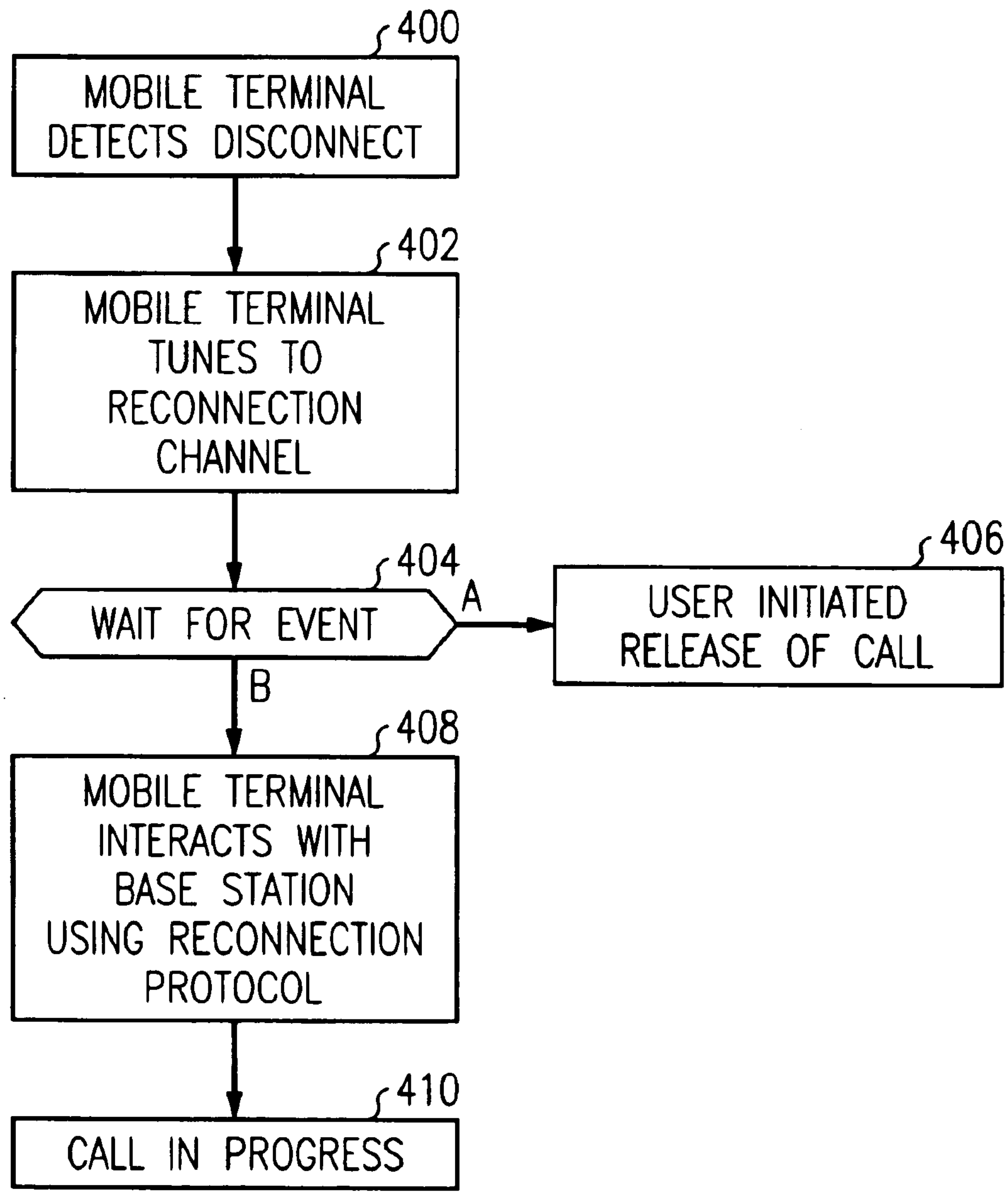
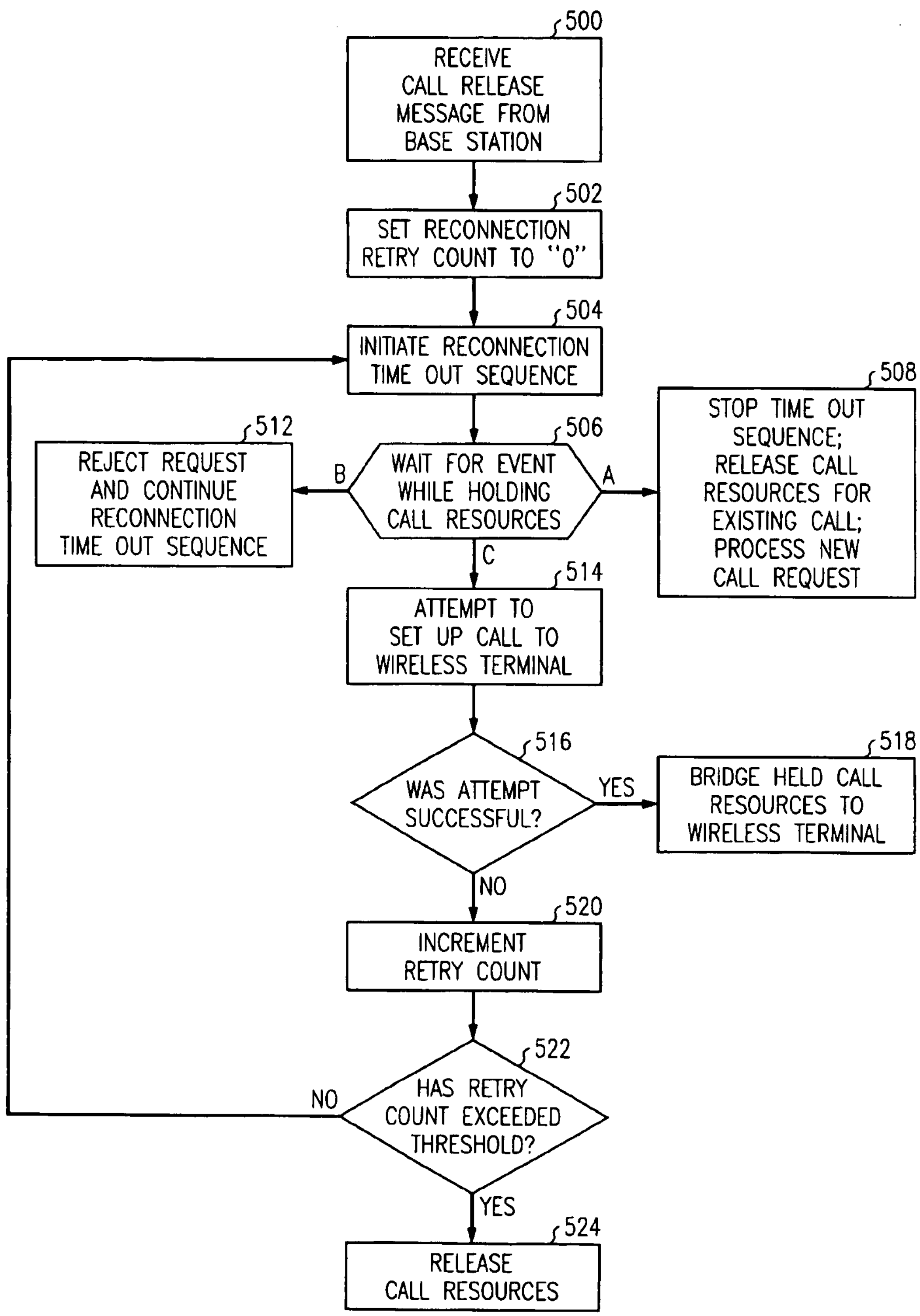

400
MOBILE TERMINAL DETECTS DISCONNECT
402
MOBILE TERMINAL TUNES TO RECONNECTION CHANNEL
404
WAIT FOR EVENT
A
406
USER INITIATED RELEASE OF CALL
B
408
MOBILE TERMINAL INTERACTS WITH BASE STATION USING RECONNECTION PROTOCOL
410
CALL IN PROGRESS

FIG. 5


500
RECEIVE CALL RELEASE MESSAGE FROM BASE STATION
502
SET RECONNECTION RETRY COUNT TO "0"
504
INITIATE RECONNECTION TIME OUT SEQUENCE
506
WAIT FOR EVENT WHILE HOLDING CALL RESOURCES
A
508
STOP TIME OUT SEQUENCE; RELEASE CALL RESOURCES FOR EXISTING CALL; PROCESS NEW CALL REQUEST
B
512
REJECT REQUEST AND CONTINUE RECONNECTION TIME OUT SEQUENCE
C
514
ATTEMPT TO SET UP CALL TO WIRELESS TERMINAL
516
WAS ATTEMPT SUCCESSFUL?
YES
518
BRIDGE HELD CALL RESOURCES TO WIRELESS TERMINAL
NO
520
INCREMENT RETRY COUNT
522
HAS RETRY COUNT EXCEEDED THRESHOLD?
NO
YES
524
RELEASE CALL RESOURCES

METHOD FOR RECONNECTING CALLS IN A WIRELESS TELECOMMUNICATIONS SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application is related to the application of Richard W. Buskens, Thomas F. LaPorta, Arun N. Netravali, and Krishnan K. Sabnani entitled "Method Of Using An Intelligent Mobile Terminal For Reconnecting Calls In A Wireless Telecommunications System", Ser. application No. 08/771,739 filed on Dec. 20, 1996, which application is assigned to the assignee of the present invention.

TECHNICAL FIELD

This invention relates to wireless telecommunications, and more particularly, to efficiently reconnecting calls in wireless telecommunications systems.

BACKGROUND OF THE INVENTION

The hallmark of wireless telecommunications services is mobility gained by the elimination of wired connections. Indeed, the ability to use a mobile terminal (such as a cellular telephone) to originate and receive calls across a wide range of geographic locations is enabled by the use of an allocated portion of radio spectrum dedicated to transmitting voice, data, and control information. More particularly, mobile terminals send and receive voice, data, and control information from base stations over an air interface. The base station serves as a gateway point between the mobile terminal and a mobile switching center. The mobile switching center provides call processing services and resource allocation for establishing call connections in the wired network which is required for connecting mobile terminals to other parties.

To establish a call, a base station allocates air traffic channels to a mobile terminal for transmitting voice, data, and control information. In one implementation, a traffic channel operates at a carrier frequency comprising time slots during which the mobile terminal transmits data frames (including synchronization bits) to the base station and vice versa. One problem with mobile telecommunications is that synchronization needed to maintain a connection between a mobile terminal and base station is often lost. The most common cause for loss of synchronization is the inability of the terminal or base station to detect the carrier frequency of the traffic channels used in the call. Another cause of loss of synchronization is the inability to receive data frames from the mobile to the base station (or vice versa) in their anticipated time slots due to obstructions such as trees, buildings, tunnels or noise interference. In current implementations, both the serving base station and the mobile terminal wait for each others carrier frequencies (or data stream) to be reinstated for a specified period (a resynchronization "time-out" period) before the loss of synchronization precipitates call release procedures tearing down the existing call in the base station. From the base station perspective, releasing a call results in releasing the air traffic channels and other resources associated with the call. If the base station fails to resynchronize, it sends a call release message indicating disconnect to the mobile switching center so that call connections to the other party (or parties) are released. In the current art, from the mobile terminal perspective, releasing a call involves termination of data traffic on the air traffic channel allocated to the call, and resetting an internal state of the terminal so that new calls can proceed.

Abnormally released calls due to loss of synchronization result in subscriber frustration and a need for reestablishing the call. Reestablishing a call requires re-dialing and reestablishing connections interconnecting the mobile terminal to its parties. Hence, reconnecting disconnected calls not only requires subscriber action but also requires duplicated network action. Therefore, there is a need in the art for efficiently reconnecting mobile calls to decrease subscriber inconvenience and enhance network efficiency when disconnected calls are reconnected.

SUMMARY OF THE INVENTION

This need is addressed and a technological advance is achieved in the wireless telecommunications art by actively attempting call reconnection for a specified time period and performing call release procedures if the reconnection attempts fail. For purposes of the present invention, call disconnect is defined as the point at which loss of synchronization would ordinarily cause a call to be released.

In the preferred embodiment, a base station establishes a reconnection channel for interaction with mobile terminals equipped with a reconnection processor. Upon detection of disconnect, the base station attempts to establish new air traffic channels interconnecting the mobile terminal. The reconnection attempts are made by the base station for a specified time period. The reconnection channel serves as a broadcast means via which the mobile terminal and the base station interact to attempt reconnection. In the event that reconnection is unsuccessful, wired network call resources associated with the existing call are released.

In another preferred embodiment, a base station selectively reinitiates a reconnection process upon expiration of a resynchronization timer. The reconnection process requires the base station to hold wired call resources while it attempts to reestablish the call to the mobile terminal. If the call attempt is successful, the base station establishes new air traffic channels to bridge the wired network call resources with the new air traffic channels so that the call may continue. The reconnection attempt is made for a predetermined number of tries before the base station abandons call reconnect efforts and releases call resources. Upon release of call resources, a call release message indicating abnormal release is transmitted to a mobile switching center.

In still another preferred embodiment of the present invention, a mobile switching center includes a reconnection timer for establishing a predetermined time period during which the mobile switching center actively attempts to reconnect calls which have been requested to be disconnected by a base station. During reconnection efforts, the mobile switching center holds call resources unaffected by the loss of synchronization. If reconnection attempts are unsuccessful, all call resources are released. If reconnection attempts are successful, the unaffected call resources are bridged with new call resources established as a result of the successful reconnect by the mobile switching center.

Advantageously, all preferred embodiments of the present invention require holding some portion of network resources during call reconnection attempts. Holding network resources allows calls to be reestablished more quickly because only portions of the call connection need to be set up and thereby eliminates the need for duplicated network effort.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified block diagram of a preferred embodiment of a wireless telecommunications system;

FIG. 2 is a flow diagram illustrating the steps performed by a base station shown in the wireless telecommunications system of FIG. 1 in accordance with the preferred embodiment of the present invention;

FIG. 3 is a flow diagram illustrating the steps performed by a base station shown in the wireless telecommunications system of FIG. 1 in another preferred embodiment of the present invention;

FIG. 4 is a flow diagram illustrating the steps performed by a mobile terminal in the wireless telecommunications system of FIG. 1 in accordance with the preferred embodiment of the present invention; and

FIG. 5 is a flow diagram illustrating the steps performed by a mobile switching center in the wireless telecommunications system of FIG. 1 in accordance with the preferred embodiments of the present invention.

DETAILED DESCRIPTION

FIG. 1 shows a simplified block diagram of wireless telecommunications system **100** including mobile switching center **120** and mobile switching center **140** interconnected to the rest of the public switched telephone network **101** via established trunks **121** and **141**, respectively. Mobile switching center **120** includes processor **128** interconnected to database **130** via data link **129**. Processor **128** includes a timing means and is responsible for performing call processing functions (such as set up and tear down of calls) and retrieving information such as routing information used to set up a call from database **130**. In this embodiment, mobile switching center **120** serves base stations **122**, **124** and **126** via established base station links **123**, **125** and **127** respectively. In the preferred embodiment, each base station includes a processor (with embedded memory and timing means) for administering call reconnection protocols as described below. Base stations **122**, **124** and **126** include processors **132**, **134** and **136**, respectively. In this example, mobile terminal **135** is served by base station **122**. Established air interface connection **131** indicates that mobile terminal **135** is active in a call.

Mobile switching center **140** includes processor **148** interconnected to database **150** via data link **149**. Processor **148** includes a timing means and is responsible for performing call processing functions (such as set up and tear down of calls) and retrieving information such as routing information used to set up a call from database **150**. In this example, mobile switching center **140** serves base stations **142**, **144** and **146** via base station links **143**, **145** and **147**, respectively. Similar to mobile switching center **120**, each base station includes a processor with embedded memory and timing means for administering reconnection protocols, as described below. In this example, base stations **142**, **144** and **146** include processors **152**, **154** and **156**, respectively. Mobile terminal **155**, served by base station **142**, is interconnected to the base station via air interface connection **151**. In the preferred embodiment, mobile terminal **155** includes antenna **157** and reconnection processor **159** for responding to a base station using a reconnection protocol. The reconnection protocol is administered by the base station over an established reconnection channel. In this embodiment, base station **142** has dedicated reconnection channel **153** for operating the reconnection protocol.

Calls involving mobile terminals **135** and **155** are established using known procedures which allow voice and data transmissions to be relayed from a base station to a mobile terminal and vice versa. Occasionally, the air interface between the base station and the mobile terminal is obstructed resulting in a loss of synchronization and call release if resynchronization cannot be achieved. In accordance with the preferred embodiment, an active attempt to reconnect the portion of the connection affected by loss of synchronization calls is made before network call release procedures are invoked.

FIG. 2 illustrates the steps performed by a base station to reconnect a call in accordance with one preferred embodiment of the present invention. More particularly, FIG. 2 illustrates the steps performed by base station **122** (that is, a base station without a dedicated reconnection channel) in reestablishing a call.

For purposes of example, assume that a subscriber using mobile terminal **135** is involved in a call with a party served by public switched telephone network **101**. Accordingly, air traffic channel **131** is established to transmit voice between mobile terminal **135** and the customer premises equipment of the other party (not shown) via base station **122**, mobile switching center **120** and trunk **121**. Also assume that the data flow between mobile terminal **135** and base station **122** is interrupted due to loss of synchronization. The reconnection process begins in step **200** in which base station **122** detects disconnect of the call (that is, the loss of synchronization is detected and the resynchronization time-out sequence has expired without successfully resynchronizing to the mobile terminal). The base station recognizes the disconnect to be involuntary (as opposed to a user simply ending a call by hanging up) because no formal call release message is received.

In decision step **202**, base station **122** determines whether reconnection procedures should be attempted. More particularly, decision step **202** allows base station **122** to selectively deploy the reconnection process. In some circumstances, such as an unusually heavy call volume, base station **122** may be programmed to immediately release call resources upon detection of a disconnect. If the outcome of decision step **202** is a "NO" determination, the process continues to step **203** in which base station **122** initiates call release procedures and sends a call release message indicating disconnect to mobile switching center **120**. If the outcome of decision step is a "YES" determination, the process continues to step **204** in which base station **122** sets a reconnection retry count to "zero". In step **206**, the base station begins a reconnection time-out sequence during which the base station attempts to establish new air traffic channels to be used between base station **122** and mobile terminal **135**. In step **207**, base station **122** waits for an event to occur while holding call resources associated with the interrupted call. Each of the possible events is discussed in detail below.

The process continues through connector A when the reconnection time-out sequence has expired. In step **208**, base station **122** makes an attempt to reestablish the portion of the connection affected by the loss of synchronization. In decision step **210**, base station **122** determines whether the reconnection attempt was successful. If the outcome of decision step **210** is a "YES" determination, the process continues to step **212** in which base station **122** uses new air interface resources (i.e., traffic channels) in the call with the mobile terminal. If the outcome of decision step **210** is a "NO" determination, the process continues to step **214** in which the reconnection retry count is incremented. The process continues to step **216** in which base station **122** determines whether the reconnection retry count has been incremented beyond a predetermined threshold. If the outcome of decision step **216** is a "NO" determination, the process returns to step **206** in which the reconnection

time-out sequence is initiated. If the outcome of decision step **216** is a "YES" determination, the process continues to step **218** in which base station **122** sends a call release message indicating disconnection to the mobile switching center. In step **220**, the base station releases all call resources associated with the disconnected call.

The process continues through connector B when another incoming call directed to mobile terminal **135** has been received during the time-out sequence. The process continues to step **222** in which the incoming call request is rejected and the time-out sequence is continued. In alternative embodiments, the incoming call request may be honored. In these embodiments, the time-out sequence is halted, call resources associated with the disconnected call are released, and the incoming call is processed as a new call request.

The process continues through connector C when the subscriber using mobile terminal **135** attempts to originate a call during the time-out sequence. The process continues to step **224** in which the time-out sequence is terminated, call resources for the existing call are released and the new call request is processed.

FIG. **3** is a flow diagram illustrating the steps performed during another preferred embodiment of the present invention. More particularly, FIG. **3** describes the steps performed by base station **142** which includes reconnection channel **153** for relaying messages to a mobile terminal. For the reconnection channel to be functional, the mobile terminal involved in the call must be equipped with a reconnection processor. For purposes of explanation, assume that a subscriber is involved in a call using mobile terminal **155** (that is, a mobile terminal including a reconnection processor) when a loss of synchronization occurs and a resynchronization timer expires. The process begins in step **300** in which base station **142** detects call disconnect

The process continues to decision step **302** in which base station **142** determines whether reconnection procedures should be attempted for this particular call. If the outcome of decision step **302** is a "NO" determination, the air traffic channel interconnecting base station **142** to mobile terminal **155** is released and a call release message indicating the disconnect is sent to the mobile switching center in step **303**. If the outcome of decision step **302** is a "YES" determination, the process continues to step **304** in which base station **142** sets a reconnection retry count to "zero". In step **305**, the base station initiates a reconnection time-out sequence. In step **306**, base station **142** broadcasts a reconnection message to mobile terminal **155** over reconnection channel **153** while holding all resources associated with the call. Although reconnection channel **153** is shown to exclusively serve terminal **155**, other embodiments may use a global channel to serve all mobile terminals. In the preferred embodiment, the reconnection message instructs the mobile terminal to tune to new air traffic channels so that the call may be reconnected. In other embodiments, base station **142** sends a message over the reconnection channel informing mobile terminals to request new resources.

During the broadcast, a variety of events may occur. First, the subscriber associated with mobile terminal **155** may elect to originate a call. If this event occurs, the process continues through connector A to step **310** in which the time-out sequence is halted, a call a release message is sent to the mobile switching center and the new call request is processed. If the subscriber calls the disconnected party, resources may be bridged without tearing down the existing call. Secondly, the mobile subscriber associated with mobile terminal **155** may also explicitly elect to reconnect the call. This election is signaled by the wireless subscriber sending a message to the serving base station (e.g., the subscriber may depress keypad buttons *56 to indicate that reconnection is desired) over the reconnection channel. If the subscriber requests reconnection, the process continues through connector B to step **314** in which base station **142** accesses its database to retrieve subscriber information relating to mobile terminal **155**. The process continues to decision step **316** in which base station **142** determines whether there are any air traffic channels available to reconnect the previously disconnected call. If the outcome of decision step **316** is a "YES" determination, the process continues to step **318** in which the base station stops the reconnection time-out sequence and bridges the held call resources with those connecting the base station to the mobile terminal. If the outcome of decision step **316** is a "NO" determination, the process continues to step **322** and all call resources associated with the call are released. Also, a call release message indicating disconnect is sent to the mobile switching center.

Another event which may occur during the time-out sequence is that a new incoming call may be directed to mobile terminal **155**. In this case, the process continues through connector C to step **320** in which the incoming call request is rejected and the time-out sequence is continued until the time-out expires. If the time-out sequence expires, the processor continues to step **322** in which base station **142** sends a call disconnect message to the mobile switching center so that all call resources may be released.

FIG. **4** is a flow diagram illustrating the steps performed by a mobile terminal during a reconnection attempt. For purposes of clarity, continue with the example of mobile terminal **155** involved in a call when a loss of synchronization and expiration of a resynchronization timer occurs. In this example, base station **142** serving mobile terminal **155** has established reconnection channel **153** for administering a reconnection protocol. Reconnection processor **159** contained within mobile terminal **155** allows the terminal to interact with base station **142** over reconnection channel **153**. The process begins in step **400** in which mobile terminal detects call disconnect.

The process continues to step **402** in which reconnection processor **159** tunes to reconnection channel **153** using antenna **157**. In step **404**, mobile terminal **155** waits for an event. If the process continues through connector A to step **406**, the user of mobile terminal **155** releases its resources associated with the call. If a reconnection message is received, the process continues through connector B to step **408**. In step **408**, mobile terminal **155** interacts with the base station using the reconnection protocol. In the preferred embodiment, the reconnection protocol involves transmitting information (either initiated by the mobile terminal or by the base station) for reestablishing the air interface portion of the call. The process continues to step **410** in which the call is in progress.

FIG. **5** illustrates the steps performed by a mobile switching center equipped with call reconnection capabilities. The process begins in step **500** in which the mobile switching center receives a call release message indicating disconnect from a base station. In step **502**, the mobile switching center sets a reconnection retry count to "zero". In step **504**, a reconnection time-out sequence is initiated during which all call resources are held. In step **506**, the mobile switching center waits for an event to occur. If a subscriber using mobile terminal **155** attempts to place a call during the time-out sequence, the process continues through connector A to step **508** in which the time-out sequence is terminated, call resources for the existing call are released, and the new

call request is processed. If an incoming call request is directed to mobile terminal **155**, the process continues through connector B to step **512** in which the incoming call request is rejected and the tine-out sequence is continued. In alternative embodiments, however, the incoming call request may be honored. If the time-out sequence expires, the process continues through connector C to step **514** in which the mobile switching center attempts to set up an incoming call to the mobile subscriber associated with mobile terminal **155** via base station **140**. In decision step **516**, the mobile switching center determines whether the incoming call setup request was successful. If the outcome of decision step **516** is a "YES" determination, the process continues to step **518** in which held call resources are bridged to the new call setup to the mobile terminal. If the outcome of decision step **516** is a "NO" determination, the process continues to step **520** in which the reconnection retry count is incremented. In decision step **522**, the mobile switching center determines whether the reconnection retry count has been incremented beyond a predetermined threshold. If the outcome of decision step **522** is a "YES" determination, the call is released in step **524**. If the outcome of decision step **522** is a "NO" determination, the process return to step **504** in which the reconnection time-out sequence is reinitiated.

During all of the above-described preferred embodiments, it is assumed that the other party involved in the call (that is, the party other than the user of wireless terminals **135** or **155**) maintains the connection while reconnection attempts occur. Preferably, an announcement message informing the party to hold the connection while reconnect is attempted is issued.

Advantageously, the preferred embodiments of the present invention allows a mobile terminal, base station and a mobile switching center in a wireless telecommunications system to hold call resources while reconnection attempts are made resulting in a more efficient use of network for reconnection. Further, the preferred embodiments of the present invention allow the mobile switching center and the base station to make a determination as to whether reconnection attempts will occur. For example, if it is determined that there is heavy call volume, either the base station or the mobile switching center may elect to forego reconnection attempts. In this manner, the wireless telecommunications service providers are afforded with flexibility regarding reconnection attempts.

Although this invention has been described with respect to preferred embodiments, those skilled in the art may devise numerous other arrangements without departing from the scope of the invention defined in the following claims.

The invention claimed is:

1. A wireless telecommunications system comprises:

a mobile switching center interconnected to a plurality of base stations for serving wireless subscribers;

a base station served by the mobile switching center, the base station including means for issuing a re-connection message to a mobile terminal upon loss of synchronization of a call connection, said connection message for re-establishment of said call connection between said base station and said mobile terminal, the same base station holding call resources associated with the call connection during issuance of the re-connection message; and

means for interacting with said mobile terminal over a reconnection channel established by the base station.

2. A method for re-establishing call connections affected by a loss of synchronization comprises the steps of:

in a base station, detecting call disconnect through loss of synchronization for a call;

initiating a time-out sequence during which attempts are made by said base station from which the call was disconnected to reconnect the call, said base station holding resources associated with the call during the reconnect attempt; and

terminating attempts to reconnect the call upon occurrence of an event.

3. The method of claim **2** wherein terminating reconnection attempts upon the occurrence of an event comprises the step of:

terminating attempts to reconnect the call upon lapsing of a predetermined reconnection time-out sequence.

4. The method of claim **2** wherein the step of terminating attempts to reconnect the call upon the occurrence of an event comprises the step of:

terminating attempts upon receipt of a mobile originated call request from a party involved in the call.

5. The method of claim **2** further comprising the step of:

the base station determining whether reconnection attempts should be made.

6. The method of claim **2** further comprising the step of :

the base station issuing a call release message indicating disconnect to a mobile switching center responsive to an unsuccessful attempt to reconnect the call.

7. The method for efficiently re-establishing call connections to a mobile terminal comprising the steps of:

receiving a call release message indicating loss of synchronization;

initiating a time-out sequence responsive to receipt of the call release message; and

attempting to reestablish a call connection to a wireless subscriber identified in the call release message using held resources of a base station which served the call connection.

8. The method of claim **7** further comprising:

receiving an incoming call request directed to the wireless subscriber associated with the call release message during the time-out sequence; and

rejecting the incoming call request.

9. The system of claim **1**, further comprising:

means for initiating a time-out sequence during which said base station issues said reconnection message; and

means for terminating attempts to reconnect the call upon occurrence of an event.

10. The apparatus of claim **9**, in which said means for terminating attempts to reconnect the call upon the occurrence of an event, comprises means for terminating attempts to reconnect the call upon the lapse of said time-out sequence.

11. The system of claim **9**, wherein the means for terminating attempts to reconnect the call upon occurrence of an event are responsive to receipt of a mobile originated call request from the party involved in the call to terminate attempts to reconnect the call.

12. The system of claim **1**, further comprising:

means for issuing a call release message from the base station to the mobile switching center in response to an unsuccessful attempt to reconnect the call.

13. The system of claim **9**, further comprising:

means for broadcasting reconnection information on a reconnection channel established for the reconnection attempt.

14. In a wireless telecommunications system, a method for re-establishing a call connection affected by loss of synchronization, comprising the steps of:

detecting a loss of synchronization on said call;

responsive to said detecting, in a base station for serving said call, issuing a reconnection message, for re-establishing a connection for said call, to a mobile terminal on said call;

in said base station, holding call resources associated with the call during issuance of the reconnection message; and

interacting with said mobile terminal over a reconnection channel established by said base station.

15. The method of claim **14**, further comprising the step of:

initiating a time-out sequence during which attempts are made by said base station from which the call is disconnected, to reconnect the call; and

terminating attempts to reconnect the call upon the occurrence of an event.

16. The method of claim **15**, wherein the step of terminating attempts to reconnect the call upon the occurrence of an event comprises the step of:

terminating attempts to reconnect the call upon lapsing of a predetermined reconnection time-out sequence.

17. The method of claim **15**, wherein the step of terminating attempts to reconnect the call upon occurrence of an event, comprises the step of:

terminating attempts to reconnect the call upon receipt of a mobile originated call request from a party involved in the call.

18. The method of claim **14**, further comprising the step of:

the base station issuing a call release message indicating disconnect to a mobile switching center serving said base station in response to an unsuccessful attempt to reconnect the call.

19. The method of claim **14**, wherein the step of issuing a reconnection message comprises the step of broadcasting reconnection information on a reconnection channel established for the reconnection attempt.

* * * * *